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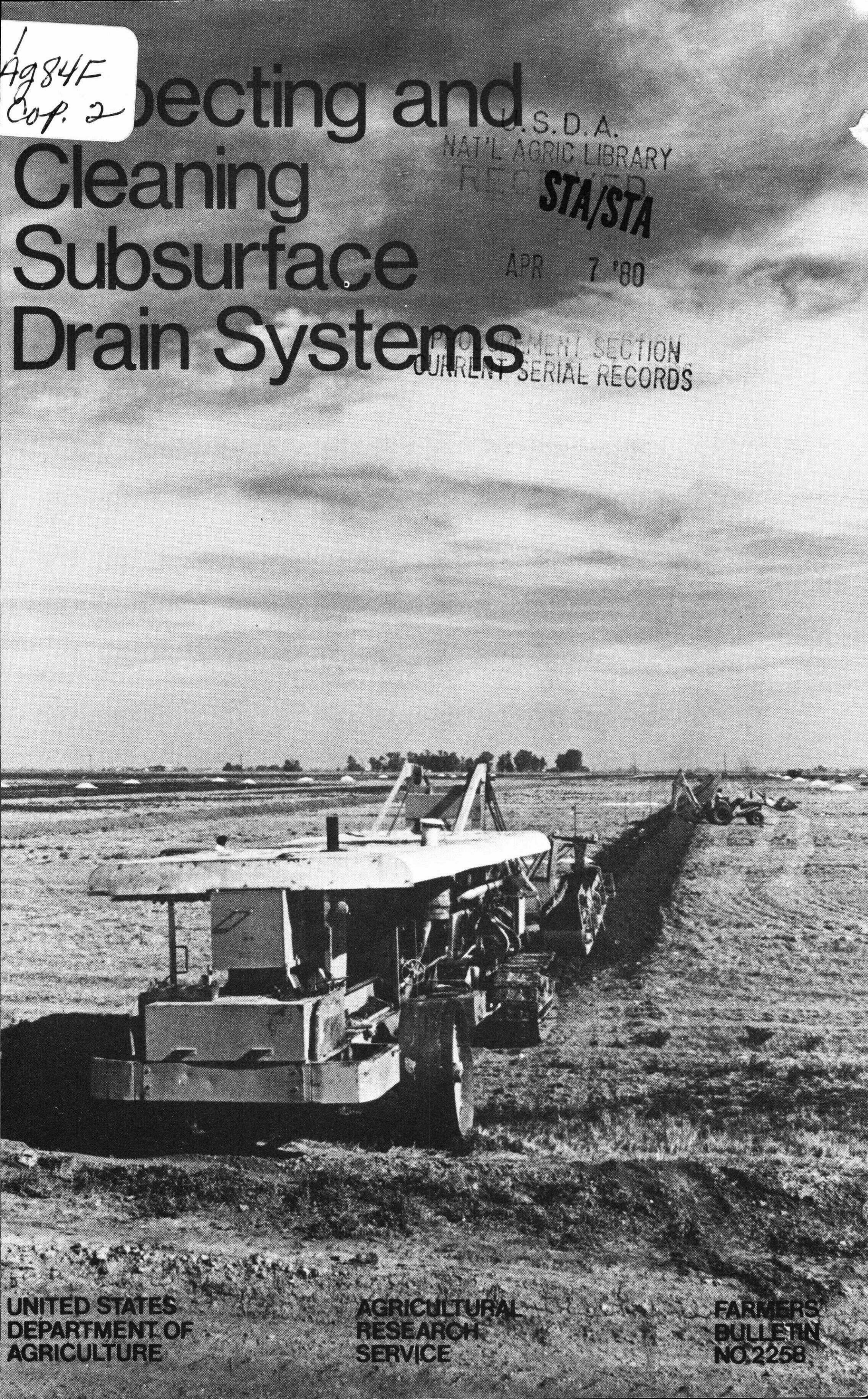
pecting and Cleaning Subsurface Drain Systems



UNITED STATES
DEPARTMENT OF
AGRICULTURE

AGRICULTURAL
RESEARCH
SERVICE

FARMERS'
BULLETIN
NO. 2258

CONTENTS

Washington, D. C.

Issued July 1975
Slightly revised September 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office
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INSPECTING AND CLEANING SUBSURFACE DRAIN SYSTEMS

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Recently developed methods for cleaning subsurface drains make it possible to clean extensive drain systems effectively, rapidly, and cheaply. As a result, a farmer can clean his drains many times if necessary rather than install a new system.

A subsurface drain system must be properly designed and installed to efficiently remove excess water and salt from the soil. In humid areas, excess water removal is the primary consideration. In arid, irrigated areas, control of salt is another important reason for installing subsurface drains. The drain openings, such as the joints of concrete or clay tile, the perforations in plastic pipes, and the interiors of all pipes, must remain open and clean for the drains to function properly.

In a field with a well-designed drainage system, two indications of developing problems are poor crop growth in certain parts of the field and localized wet areas after most of the field is dry. Wet spots interfere with cultivation and eventually the crop fails to grow and these areas fill with weeds. Sometimes the water table may rise enough to cause a continuous wet spot on the surface.

When the drains do not function properly in arid areas, the ground becomes covered with a white crust of salt. Only salt-tolerant plants will grow as drainage becomes worse.

Diagnosis of drain failure at an early stage is extremely important to detect and correct the problem before crop losses become serious or topsoil is damaged.

Subsurface drainage systems are expensive, long-term investments but they are important to modern mechanized agriculture. The farmer can protect his investment and assure continuing adequate performance of his drainage system by initiating an inspection and maintenance program as a regular part of his farming operations. Drain performance should be evaluated at least once a year on a regular basis and at any time there is a hint of a developing drainage problem.

CAUSES OF DRAIN FAILURES

The kinds of materials known to cause drain failures are mineral deposits, silt, and roots. Both sealing of the joints and clogging of the pipes can occur. In this bulletin, sealing means the closing of the drain openings through which water enters the drainpipe and clogging means a blockage of the interior of the drainpipe, causing water to back up in the pipe.

Mineral deposits that seal joints and clog drains accumulate gradually, usually starting in the joints. In some systems, the deposit may build up and seal the drain opening only to the height of maximum water level. When this happens, the drain will continue to operate, but at lowered efficiency, because the water level must rise above the affected portion to enter the drain. In other systems, the entire joint may be sealed, causing complete failure of the line. The mineral deposit problem occurs in high rainfall areas as well as irrigated areas.

Several different types of mineral deposits are found in drainage pipes and can either clog or seal them. Iron and manganese deposits have been found in drains made of all types of materials installed in a wide range of soil textures. Deposits may take from a few months to many years to develop.

The color of the deposit usually indicates the kind of mineral present. Black deposits, for example, are primarily manganese minerals (fig. 1A). Deposits of iron

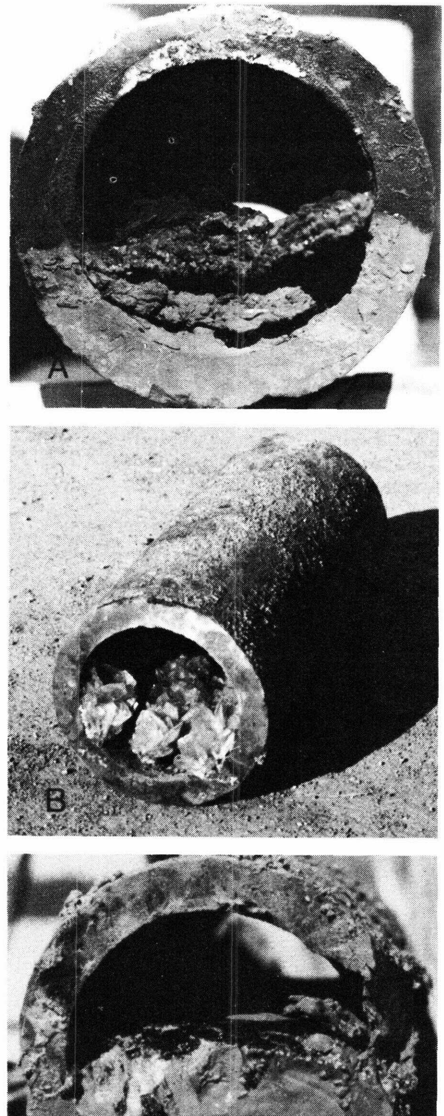

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Figure 1.—Mineral deposits sealing or clogging drains. A, Black manganese compounds; B, gypsum crystals; C, silt and manganese dioxide.

minerals are red. Iron occurs most often as a sludge or soft paste. Occasionally, it may be seen floating in drain effluents as lumps, varying from one-fourth to one-half inch in diameter. It will coat the inside of the pipe and may completely seal the joints. However, iron seldom causes drain clogging although it is often found in clogged drains.

Crystalline gypsum (calcium sulfate) deposits have been found in some drain systems, primarily in arid areas. These deposits occur mostly as beds of very small crystals. Occasionally, deposits of large hard crystals occur (fig. 1B). Two different forms of limestone (calcium carbonate) deposits have been found in drain systems. One of these is a crystalline deposit and the other is a crustlike material.

Silt is also a common cause of drain failure (fig. 1C). Silt can enter the system immediately after installation when the loose trench backfill is first saturated. A great deal of particle movement occurs during trench settling and many of the small soil particles may get into the drain if it is poorly installed or not properly protected. Drains installed in fine, uniform sand are particularly susceptible to sediment clogging. Sediment may gradually accumulate in a drain where the grade line is not true and may reduce its carrying capacity.

Broken pipe and shifts in drain alinement will permit soil particles to enter the drain system, causing sinkholes in the soil or washouts above the drain as soil washes into the pipe. Breaks in the drain should be repaired at once to prevent further damage to the system and the soil.

Roots may accumulate in drain lines in amounts sufficient to partly or completely fill them. Roots enter drains (fig. 2) when plants, especially water-loving trees, are growing near the drains during dry periods.

An ideal outlet should provide a free flow of water from the subsurface drain into the open drain ditch. The outlet should be at least 6 inches above the normal surface of the water in the open drain ditch. This is important because underwater outlets can become clogged with silt and trash.

PN-3692

Figure 2.—Root plugs such as this can cause drain failure.

INSPECTION OF DRAINS

Poor drain performance may be the result of either clogging or sealing. A close examination of the drain system is necessary to determine the cause of the problem. Excavation of the drain lines for visual inspection at various locations may be needed to fully diagnose the problem. Before excavation is attempted, a farmer should use one or all of the following three methods to determine whether his subsurface drains are operating properly.

Outflow observations.—Outflow from the drain can be measured with a bucket by timing the flow with a stopwatch or by using the sweep second hand of a wristwatch. An efficient drain should flow at a much higher rate following a rain or irrigation. For example, if the water is about 3 inches deep in the drain outlet at maximum flow, then it should decrease to about three-fourths of an inch deep in 3 to 4 days after the rain or irrigation stops.

The rate of flow in gallons per minute from the outlet can be calculated by dividing the capacity of a bucket by the time in seconds required to fill the bucket, and then multiplying by 60. For example, suppose that 3 seconds are required to fill a 5-gallon bucket. The flow calculation would be:
$5/3 \text{x} 60 = 100$ gallons per minute.

Farmers with newly installed systems should measure the outflow rate three or four times during the first year after installation to determine peak discharge. An average of these measurements will represent the discharge rate while the system is operating at maximum efficiency. This information can be used to detect a decline in the performance of the system in future annual tests of system performance.

Water table observations.—The water table directly over the drain should be at drain depth the day after a rain or irrigation stops. The water table in the soil midway between the drains should drop as the drain discharge decreases. The depth to the water table can be observed in an open post hole or auger hole dug for that purpose. The water table observation holes should be approximately as deep as the drain lines.

If the ground has become dry before a rain or irrigation, the drains may not run immediately because of the additional time and water required to soak the soil down to the level of the drains. In this case, the water table should not be above the level of the drains.

Chemical observations.—In irrigated areas, chemical laboratory analysis of water samples may give clues to system performance. The salt content of these water samples is determined by measuring the electrical conductivity. A high salt content may indicate a poorly operating drain system, particularly if the electrical conductivity remains high after irrigation. To get the electrical conductivity measured, a farmer

should contact his county agent, State experiment station, Soil Conservation Service representative, or a private laboratory.

Soil salinity measurements may also be used to detect changes in tile drain efficiency. Annual field soil sampling and measurement of the electrical conductivity of the saturation paste extract will indicate whether the soil salinity is increasing. Increasing salinity of the soil may indicate a problem with the subsurface drainage system or a need for more careful irrigation water management.

After the necessary field observations have been made, the following conclusions may be made about a drain system:

(1) The absence of a water table and no increase in the drain flow after a rain or irrigation may indicate that the water did not soak into the soil to the depth of the drains.

(2) A high water table after rain or irrigation that does not decline in a few days indicates the drain may be either clogged or sealed, or the space between drain lines may be too wide for the type of soil.

(3) Drain lines that do not flow and a high water table directly over the drain lines indicate clogged lines or sealed joints.

(4) If the drain is full of water and the water table in the soil is above the drain, a plugged or overloaded drain is indicated.

The cost of excavation to inspect the drains can be saved if the above observations indicate the system is in good operating condition. However, if the observations indicate the drain system is clogged or sealed, it should be excavated for visual inspection and diagnosis.

EXCAVATION OF DRAINS

If excavation is necessary to inspect the interior of the drains, excavate at least two locations on the suspected drains. Make the first opening at the junction of a lateral and the collector, or baseline, drain. Deposits of manganese and iron are often most severe in the laterals near the baseline.

Broken and decaying roots may collect at junctions and form root plugs. An opening at a junction makes it possible to inspect both the baseline and the lateral from a single point. Make the second excavation two-thirds to three-fourths of the distance to the upper end of the lateral to determine the extent of the sealing or clogging.

Pay close attention to the soil as the excavation progresses to observe the appearance of roots, iron, or manganese or poorly drained blue-gray soil. The final few inches of soil above the pipe should be removed by hand so any protective sand, gravel, or other envelope material around the drain can be closely inspected to determine whether or not the envelope has been sealed by deposits

of iron or manganese. Inspect the joints to detect possible sealing before opening the pipe to examine the interior.

When the drain is fully exposed, carefully cut or break an inspection hole in the top of the pipe. A hammer and chisel, geologist's tool, or other tool designed for cutting very hard materials such as concrete can be used to open a hole in clay or concrete drain pipe. A knife can be used to cut plastic pipe.

After the hole is cut, the drain can be inspected visually to see whether or not it is clogged or sealed, and if it is, the kind of clogging or sealing material that is present. A decision can then be made about what is needed to correct the problem.

CLEANING DRAIN SYSTEMS

The method to use in cleaning a drain system depends on the material causing the problem and the extent and severity of clogging of the interior of the pipe or sealing of the drain openings.

Water Jet Cleaning

Water jet cleaning is effective for many clogging and sealing problems. High-pressure jetting equipment, such as contractors use for cleaning sewers, utilizes the extreme cutting action of water jets to dislodge and move obstructions. Jets of water exiting at various angles from special cleaning nozzles can dislodge deposits of silt or minerals and cut roots that may be present. Water from jets on the rear of the nozzle washes the dislodged material out of the drain and propels the nozzle and the hose up the inside of the drain pipe.

Two types of nozzles are commonly used to clean tile drain pipes. They are cleaning nozzles and penetrator nozzles. The cleaning nozzle is effective for removing silt, small roots, and soft mineral deposits from the joints and

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High-pressure jet cleaning equipment is expensive. It may not be practical for a farmer to build or buy equipment to clean his own drain system because he might not use it but once in 3 to 5 years. A farmer should normally contract with a commercial drain cleaning firm to clean his drain system when one of these firms is located in the area. Otherwise, the equipment could be acquired by a soil conservation, drainage, or irrigation district, or some other cooperative organization in areas where commercial cleaning services are not available. It would be best to train a crew to operate the equipment, which could then be available to farmers on a loan or rental basis.

Operators usually become very efficient with experience and learn to recognize problems such as a break in the drain by the appearance of excess sand or soil at the access opening during cleaning.

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interior of the drain pipe. The penetrator nozzle is required to break through dense silt or mineral deposits and heavy root masses.

Ordinarily, a cleaning nozzle does not have a forward jet as does a penetrator nozzle. A cleaning nozzle has five jets located around the circumference at mid-nozzle and placed at a 90 degree angle to the longitudinal axis (fig. 3A). These jets scour the interior surfaces of the pipe as well as the joints and openings. Five additional jets are located around the rear of the nozzle and placed at a 30 degree angle to the longitudinal axis.

The purpose of the rear jets on a cleaning nozzle is to propel the nozzle forward, to create high turbulence within the drain, and to provide sufficient water to keep material floating until it reaches an opening in the drain where it can be removed by a dewatering pump. Dewatering pumps can pump water, slurry, and material suspended in the water. They are the types used by waterworks repair crews to remove mud and water from excavations made to repair broken water lines.

If the cleaning nozzle cannot dislodge the material plugging the drain pipes, a penetrator nozzle must be used. A penetrator nozzle has five rear jets placed at a 15 degree angle to the longitudinal

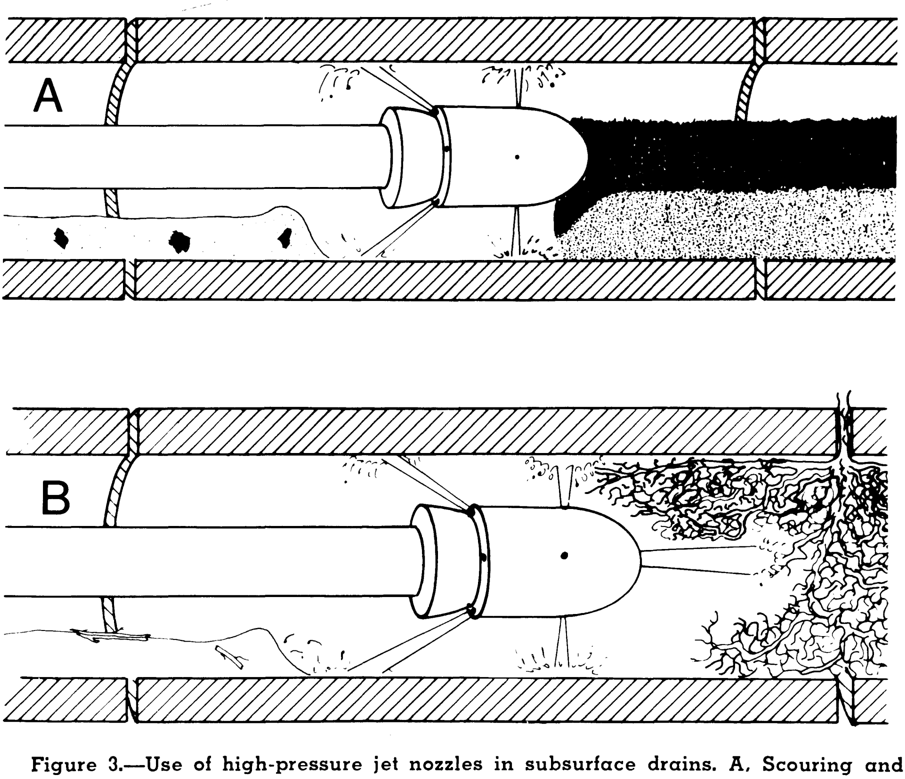

Figure 3.—Use of high-pressure jet nozzles in subsurface drains. A, Scouring and removing silt and mineral deposits; B. removing roots.

axis (fig. 3B). The low jet angle gives it the additional forward thrust needed to penetrate accumulations of roots and silt, which may be clogging the drain. This nozzle also has a jet in its nose that can disrupt deposits and cut through accumulations of roots. The penetrator nozzle can remove root plugs and cut roots up to one-quarter inch in diameter.

Root plugs are caused by small dead roots that break off and lodge at a single location such as a rough joint or a junction. Live roots may develop in a large mass in the drain and seriously impede water flow. The roots of trees and shrubs may grow into drain pipes in sufficient quantity to clog them. Some of these roots may reach one-quarter inch in diameter.

Jet cleaning procedure

Each lateral to be cleaned must be excavated at the intersection with the baseline or slightly below the section to be cleaned. After the drain pipe has been exposed, use a hammer and chisel or a geologist's tool to cut or break a section of the pipe so that the top one-third to one-half of the pipe can be lifted out. Retain the section removed for later replacement. Place a plumber's inflatable rubber plug in the pipe at the downstream end of the opening to keep deposits from moving downstream.

A pumper truck and a water supply truck (fig. 4) are commonly used by commercial drain or sewer cleaning contractors to clean drains. The pumping pressure on this equipment is normally about 1,250 pounds per square inch and the nozzle pressure is 800 pounds per square inch. The pumping rate is approximately 60 gallons per minute.

The operator's assistant inserts the nozzle and hose into the drain opening and begins the pumping operation (fig. 5). The nozzle will move upstream in the drain at rates up to 45 feet per minute, depending on the amount of foreign material in the pipe, until the entire length of hose (600–700 feet) is dispensed. The operator begins withdrawing the hose immediately while continuing the jetting action.

The water deposits washed back to the drain access opening are simultaneously removed by the dewatering pump and are discharged on the ground surface 20 or more feet away from the excavated area as shown in figure 6. The operator should continue to clean the drain, running the jet in and out repeatedly until the water returning to the access opening becomes clear. In seriously clogged lines, five or six complete jettings are often necessary to remove all deposits.

Repeat the cleaning procedure across the field until the lower length of each lateral has been cleaned. This cleaning length usually is 700 feet, or slightly less than the length of the hose on the jetting unit.

A second set of excavations is made 650 feet upstream along the drain from the previous opening to facilitate cleaning the next sec-

tion of drain. This allows 50 feet of previously cleaned length of pipe to be cleaned again if any deposit materials from further upstream have moved into this portion of the drain. Repeat the excavations and cleaning until the entire length of each lateral has been cleaned. Clean the baseline last to remove any sediment washed into it while cleaning the laterals.

During cleaning, misalinements or breaks in the drain are indicated by the appearance at the cleaning opening of large quanti-

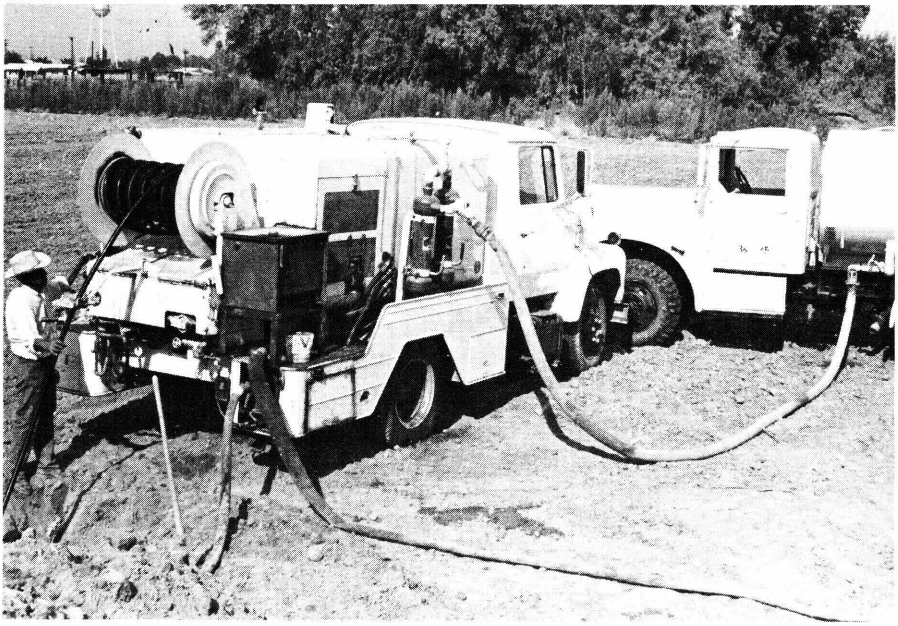

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Figure 4.—Hose from tanker supply truck (right) is attached to filters of pumper truck (left) to remove sand particles and trash from water before hose enters storage tank supplying water to high-pressure pump and jet nozzle. Operator dispenses or withdraws jetting hose from drain line using power-operated reel at rear of pumper truck. Dewatering pump is located at lower right corner of pumper truck.

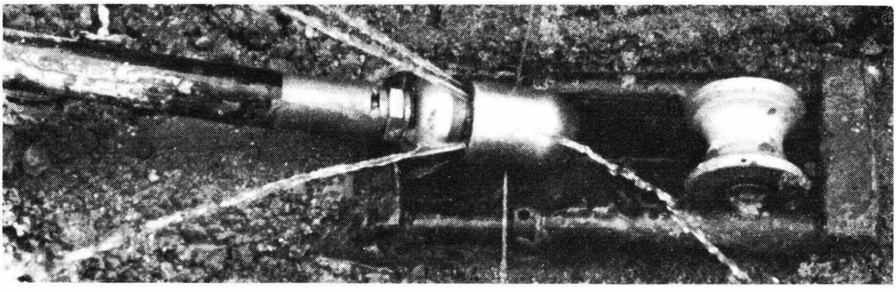

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Figure 5.—High-pressure cleaning nozzle enters tile access opening. Metal frame equipped with guiding roller surrounds rough edges of tile opening to prevent damage to hose.

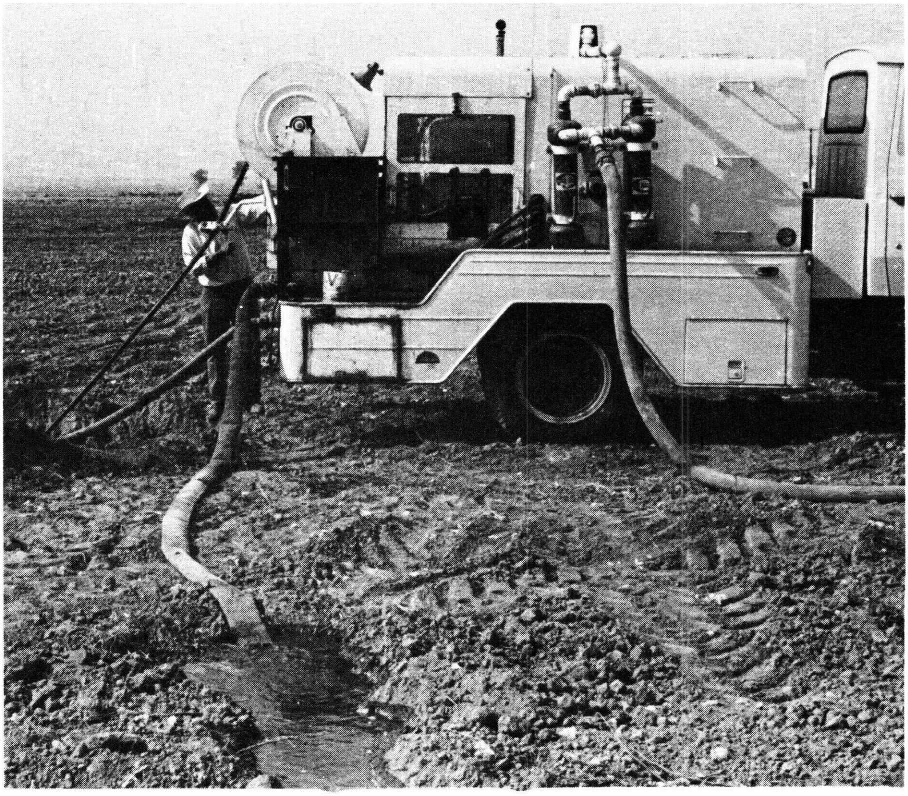

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Figure 6.—Water and solid materials dislodged by jet nozzle are pumped from access hole by dewatering pump located directly beneath hose reel. Suspended materials from access hole are discharged on ground surface during cleaning operation.

ties of soil or the sand or gravel from the drain envelope. This can be confirmed by withdrawing the nozzle and allowing it to return slowly into the pipe.

The water will be clear at the drain access opening but will become muddy when the nozzle reaches the break in the drain. The break should be located by measuring the jetting hose and should be repaired immediately by patching or replacing the defective pipe. This portion of the line is cleaned again to remove the soil and sand washed into it during the repair and previous cleaning operation.

If a high water table is present, cleaning will admit large quantities of water into the drain. If the drain flow exceeds the capacity of the dewatering pump, cleaning may be interrupted until the excess flow decreases.

When the cleaning has been completed, replace the section cut out of the drain and make sure it fits well enough to remain firmly in place. Plastic portland cement

can be used to complete the patch. Replace the sand or gravel envelope material around the entire length of exposed drain line. Place sufficient soil over the drain by hand to insure that the envelope material and patch will not be displaced when large amounts of backfill soil are dumped into the excavation. Carefully resettle the backfill material to avoid moving soil into the drain.

Observe the rate of discharge at the drain outlet, especially during the first rain or irrigation following cleaning as a reference for future performance checks. Measure the rate of discharge at this time when the drain system is functioning best. The discharge rates will usually reach a peak flow about 24 hours after the rain or irrigation begins.

The effectiveness of high pressure jet cleaning was tested in a drain system in which the joints were known to be sealed with sand and silt. The water table stood 5 feet above the drains during irrigation. The envelope material around the drain was also partially clogged with soil. The flow rate from the system was measured during 21-day periods before and after jet cleaning while the field was irrigated continuously to keep the soil filled with water.

After the system was cleaned, the maximum height of the water table over the drains was 3 feet lower and there was evidence that soil and fine particles had been removed from the envelope material, improving its hydraulic conductivity characteristics and increasing the flow of water into the drain. As a result of these improvements there was a 45-percent increase in flow rate from the system at 21 days (fig. 7).

Safety precautions

In the drain-cleaning operation, observe the common safety precautions used with all types of machinery. Shut off the pump when the nozzle gets about 2 feet from the drain access opening.

Slope the sides of the cleaning access holes to keep the walls from caving in. Some soils will be more unstable than others depending on soil texture, water content, and depth of excavation.

Sulfur Dioxide Cleaning

Drain systems found to be affected primarily by mineral manganese or iron deposits, but with little or no silt and few or no roots present, can be cleaned chemically by injecting a 2-percent solution of sulfur dioxide (SO_2) gas and water. When iron is deposited in combination with organic matter, sulfur dioxide cleaning may not be fully effective.

Cleaning procedure

To prepare a drain system for treatment, connect temporary access risers (pipes of plastic or asbestos cement) to the upper end of each lateral as shown in figure 8. This requires a single excavation at the upper end of each lateral drain. No further excava-

tions are needed unless it is desired to clean individual laterals. In this case, a second excavation is made to isolate the lateral from the rest of the system.

The drain system can be permanently modified by extending the laterals to the edge of the field or to an irrigation ditch as shown in figure 9. This modification will permit future treatments without further excavations as mineral deposits collect periodically. Treatments can also be conducted during the crop growing season without disturbing the crop.

Systems containing a large amount of loose sediment or deposit material, as revealed by the preliminary inspection, should be jet cleaned or flushed with a large flow of water pumped into the drain to remove as much loose material as possible before chemical treatment. Flushing reduces the chance of clogging during treatment from loose deposit material in the system. Flushing also makes more of the cleaning chemical available to dissolve deposits in the drain openings and inside the drain. Any leftover solution will remove deposits that may have accumulated in the envelope material or soil immediately outside the drain.

After flushing, the system is ready to be treated with the sulfur dioxide gas and water solution. The amount of gas and water needed will depend on the drain size and length of the lines. Table 1 shows the amount of water and gas needed to treat 100 feet of various drain pipe sizes.

The sulfur dioxide is injected at a controlled rate into the drain at the bottom of the access riser

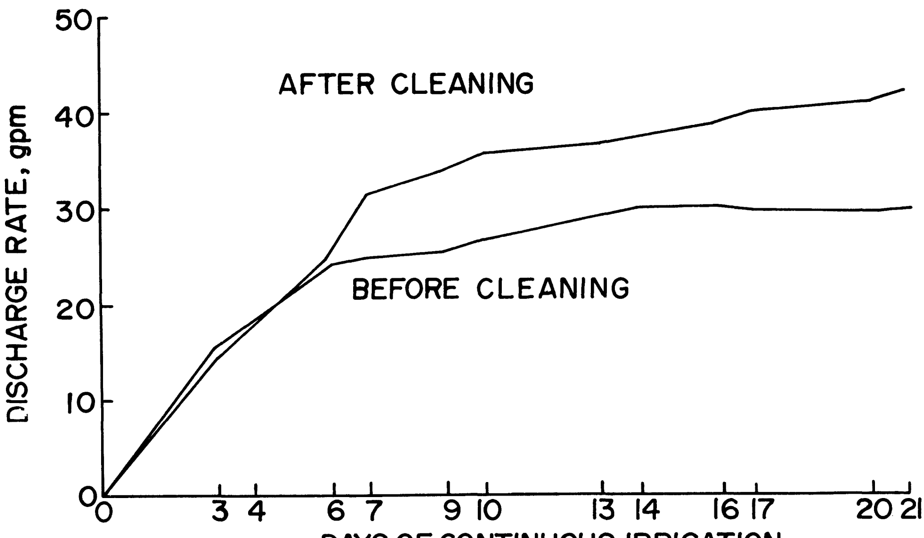

Figure 7.—Effect of jet cleaning on drain discharge.

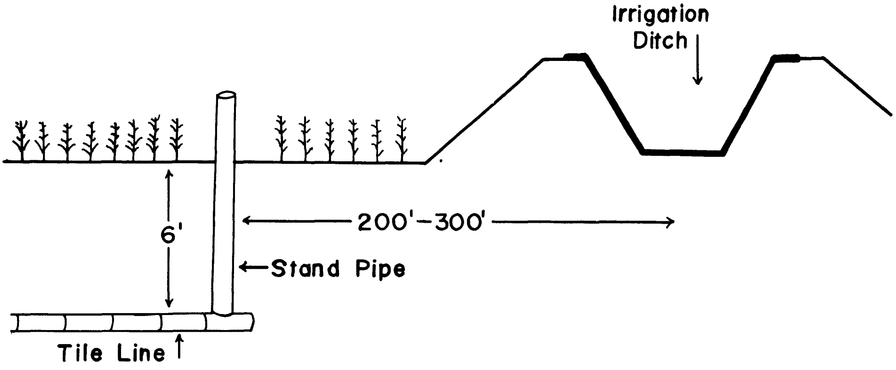

Figure 8.—Riser installed at upper end of tile line as temporary access pipe for injecting chemicals into drains.

from a pressure tank through a hose that extends to the bottom of the drain. At the same time, water is pumped at a controlled rate into the access riser to the drain through a hose that ends a short distance above the bottom of the drain. Continuous measurements of the sulfur dioxide tank weight can be made with a portable scale so the rate of gas flow can be adjusted relative to the measured rate of water flow being pumped into the drain. The flow rates of both gas and water should be balanced to obtain a solution of the proper concentration.

TABLE 1.—Quantities of sulfur dioxide (SO_2) needed for treatment of tile drains.

Tile diameter	SO_2 per[1] 100 feet	Water per 100 feet
inches	*pounds*	*gallons*
3	6.1	37
4	10.9	65
5	17.0	102
6	24.5	147
8	43.6	261
10	68.1	408
12	98.0	588

[1] A 2-percent solution of SO_2 is formed by combining SO_2 and water in the proportion of 1 pound of SO_2 to 6 gallons of water.

The gas and water are injected at a rate to maintain a 2-percent solution of sulfur dioxide or 1 pound to each 6 gallons of water. Adjust the injection rate carefully to avoid filling and overflowing the riser with sulfur dioxide and creating a gas hazard to workmen. The water pumping rate will normally be between 30 to 60 gallons per minute, requiring 5 to 10 pounds of sulfur dioxide gas per minute.

Gas flow rates will fluctuate with temperature and may decline as the gas pressure in the tank decreases, requiring a decrease in the pumping rate of the mixing water. Commercial operators often use trailer-mounted, 1-ton tanks equipped with gas and water flow meters to obtain the proper solution. Nitrogen is sometimes injected into the sulfur di-

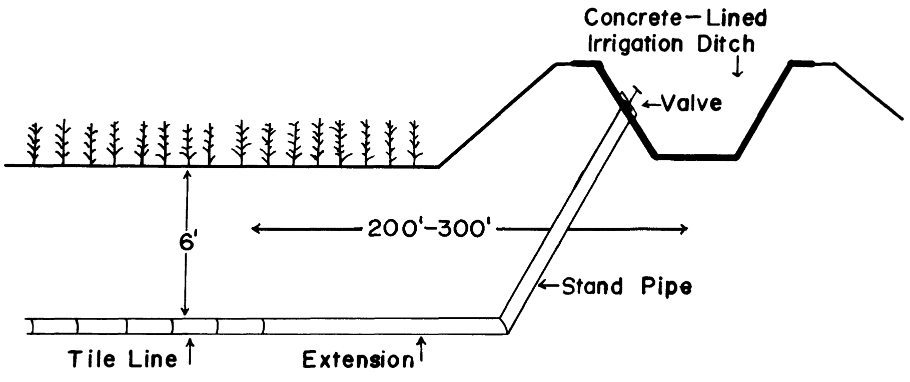

Figure 9.—Extension of tile lateral to irrigation canal as permanent access pipe for injecting chemicals into drains.

oxide tank to maintain pressure and a constant flow rate of sulfur dioxide as the tank empties (fig. 10).

A farmer can treat his drain lines himself by acquiring a portable scale, a pump, and a tank for hauling water. He can buy tanks of sulfur dioxide gas from agricultural chemical dealers in sizes small enough to be carried by one or two men. To treat the drain, the tank of gas is placed on the scale to measure the decrease in weight as the gas is being injected into the pipe. At the same time, water is pumped into the pipe at a rate to maintain the proper mixture of gas and water.

The outlet of the drain being treated should be left open at the beginning of the treatment. If individual laterals are being treated, the lower ends near the baseline should be left open. Observe the baseline outlet or the lower ends of the laterals as the treatment progresses until sulfur dioxide fumes are detected.

At this time, place a plumber's inflatable rubber plug or inflatable ball in the pipe to stop the outflow and continue injecting the solution until the calculated volume of gas and water needed to completely fill the system has been injected. When the entire system is to be treated, start with the lateral nearest to the outlet and continue from lateral to lateral in a direction away from the outlet. Thus, the system is filled with solution from the lowest elevation lateral to the highest.

Sulfur dioxide can be detected at the outlet by measuring the decline of acidity (pH) in the effluent. Litmus paper or other type of acid-indicator paper is convenient for measuring acidity changes. It can be obtained from scientific or swimming pool supply companies. The paper changes color when dipped into the liquid. If available, an acidity meter is useful.

Dyes, such as food and clothing dyes, can be put in the upper end of the first lateral to be treated as

the sulfur dioxide injection begins. The dye appears at the outlet as a flash of color.

Apply at least one tablespoonful of dye several times into the drain at 1- or 2-minute intervals. The dye will appear as a series of color flashes at the outlet, making it easier to see.

Sulfur dioxide can also be detected by its strong sulfur odor but caution should be used to avoid being overcome or burned by the fumes. An increase in acidity of drain discharge water, arrival of dyes at the outlet, or the presence of the sulfur dioxide odor is a signal to workmen to place a plug in the drain outlet because the treatment chemicals have travelled the length of the pipe being treated.

The solution should remain in the line for 3 to 4 days to allow enough time for the sulfur dioxide solution to dissolve the deposits. Then remove the plug at the downstream end of the drain to allow the system to empty. If desired, the system can be flushed with clean water again to wash out any remaining undissolved solid materials dislodged during treatment.

Treat the drain system with sulfur dioxide after a rain or irrigation has wet the soil but not when the drains are at or near peak discharge. This will minimize possible loss of solution from the drain into the soil.

If the soil has been allowed to dry to drain depth, the soil surrounding the drain can be wetted

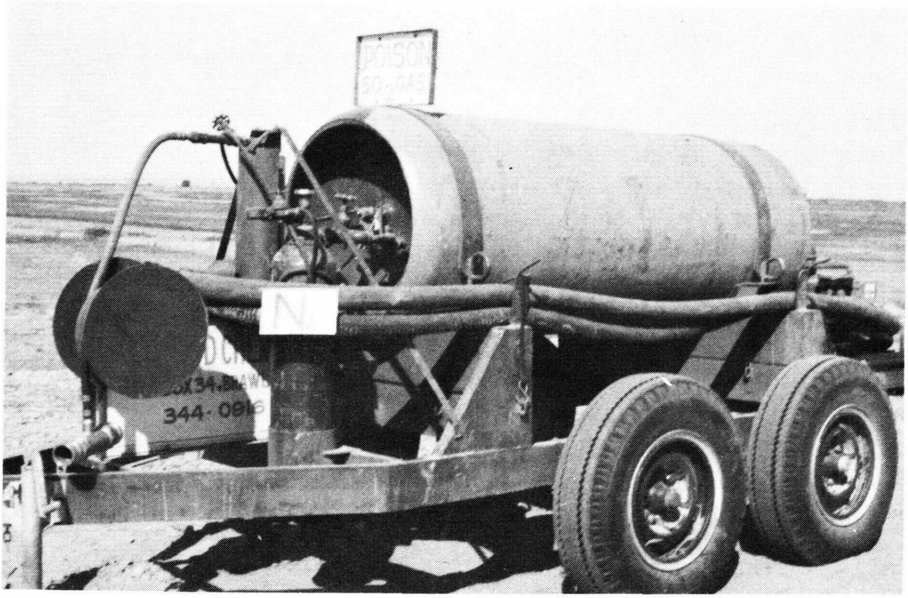

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Figure 10.—Trailer-mounted 1-ton sulfur dioxide tank with meters for regulating proper flow of gas and water.

by running water into the system with the outlet closed or by irrigating immediately before drain treatment.

Measure the outflow rate of the drains after treatment to determine the extent of improvement and then check the discharge rate at least once a year to detect possible recurrences of the problem. Some farmers routinely treat their drain systems every 2 or 3 years as a maintenance practice.

Figure 11 illustrates the improvement of an entire drain system by treating it with sulfur dioxide gas. The drain line openings in this system were sealed with manganese deposits. Before treatment, the maximum flow rate following irrigation was 15 gallons per minute. Immediately after treatment, the flow rate following irrigation was 140 gallons per minute and 2 years later it was 150 gallons per minute.

The steep rise of the flow rate curve in figure 11 shows that following irrigation, the system responded very quickly to the presence of excess water in the soil. Responses from sulfur dioxide treatments in other drain systems generally have ranged from 2- to 250-fold increases in flow rates, depending on how severely the systems were clogged.

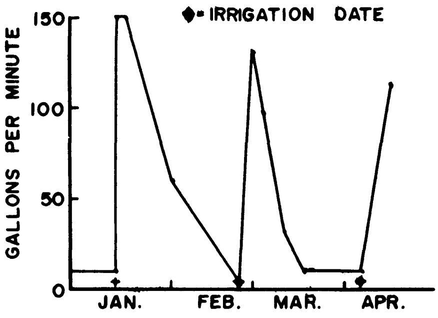

Figure 11.—Tile line flow after treatment with sulfur dioxide gas. Before treatment, peak flow was only 15 gallons per minute.

Efficient cleaning of the joints is especially important because water must enter the drain through the joints.

Safety precautions

The principal health hazards from sulfur dioxide are breathing excessive quantities of fumes or burning the eyes or skin with the liquid. The gas is intensely irritating to the eyes, throat, and upper respiratory system.

Personnel should be warned about the hazards involved in handling sulfur dioxide gas and be instructed about proper handling methods and safety precautions. Information on necessary precautions can be obtained from the gas supplier. A gas mask should always be used when entering partially closed or completely closed areas such as a sump or manhole.

U.S. GOVERNMENT PRINTING OFFICE : 1976—O-221-332

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